Ultraviolet Radiation in the Arctic

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Introduction

Ultraviolet (UV) radiation levels in the Arctic are generally considered by those who don't live in the Arctic to be quite low. The argument is simple: very low sun angles, combined with traditionally high ozone levels mean that the UV in the Arctic should be low. In fact, we have measurements that support this view. **Figure 1** shows noontime UV levels from four U.S. sites as measured by the Environmental Protection Agency's UV monitoring network. The data show strong seasonal cycles with UV in the Arctic never getting as high as UV in, for instance, Gaithersburg MD. However, this understanding of low UV levels in the Arctic disagrees with the experiences of those who live in the Arctic. **Figure 2** shows goggles that have been used for millennia by Arctic peoples to protect against snowblindness—a common Arctic eye problem that is due completely to ultraviolet radiation. The Arctic, in fact, is the only place on Earth where native inhabitants have had to develop ocular protection from ultraviolet radiation, again indicating that UV levels in the Arctic are not necessarily low.

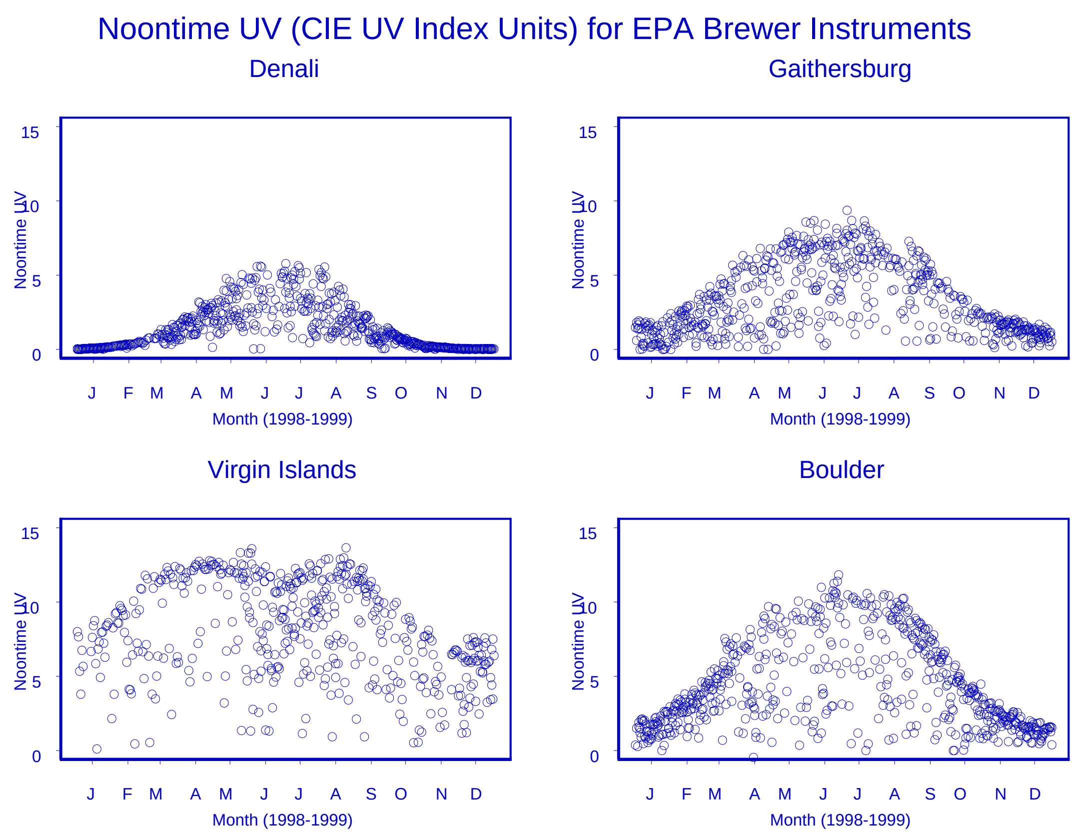

Figure 1. Noontime UV levels from Denali National Park; Gaithersburg, MD; Virgin Islands National Park; and Boulder, CO. Denali, located near the Arctic Circle, receives considerably less UV than lower latitude locations.

Figure 2. Examples of goggles used by Arctic native peoples to protect their eyes from snowblindness, a painful condition caused by UV exposure.

There are two important reasons for the disjoint between the idea that UV levels in the Arctic are low and the fact that UV effects in the Arctic are readily observable. First, daylight can be as long as twenty four hours in the Arctic, resulting in daily doses of UV to be much larger in the Arctic during times of the year when biologically production is high and humans are most likely to be outdoors. **Figure 3** shows daytime integrated UV levels from the same four U.S. sites as measured by the EPA's UV monitoring network. Once the long days are taken into account, it is clear that the UV levels in the Arctic can easily be of the same order of magnitude as UV levels found elsewhere in this country. The second factor which needs to be taken into account when considering the effects of UV radiation in the Arctic is that while these measurements represent UV reaching a flat horizontal surface, this amount does not represent the exposure to our eyes, exposed skin, shrubs and most biological receptors. If instead we consider UV to, for instance, a vertical surface, the often snow covered areas found in the Arctic magnify several times the amount of UV radiation our eyes or skin would receive. When we take into account these two factors: long days and highly reflective snow surfaces increasing UV to many biological receptors, we come to understand why UV radiation has been a natural stressor to the ecosystems and people of the Arctic.

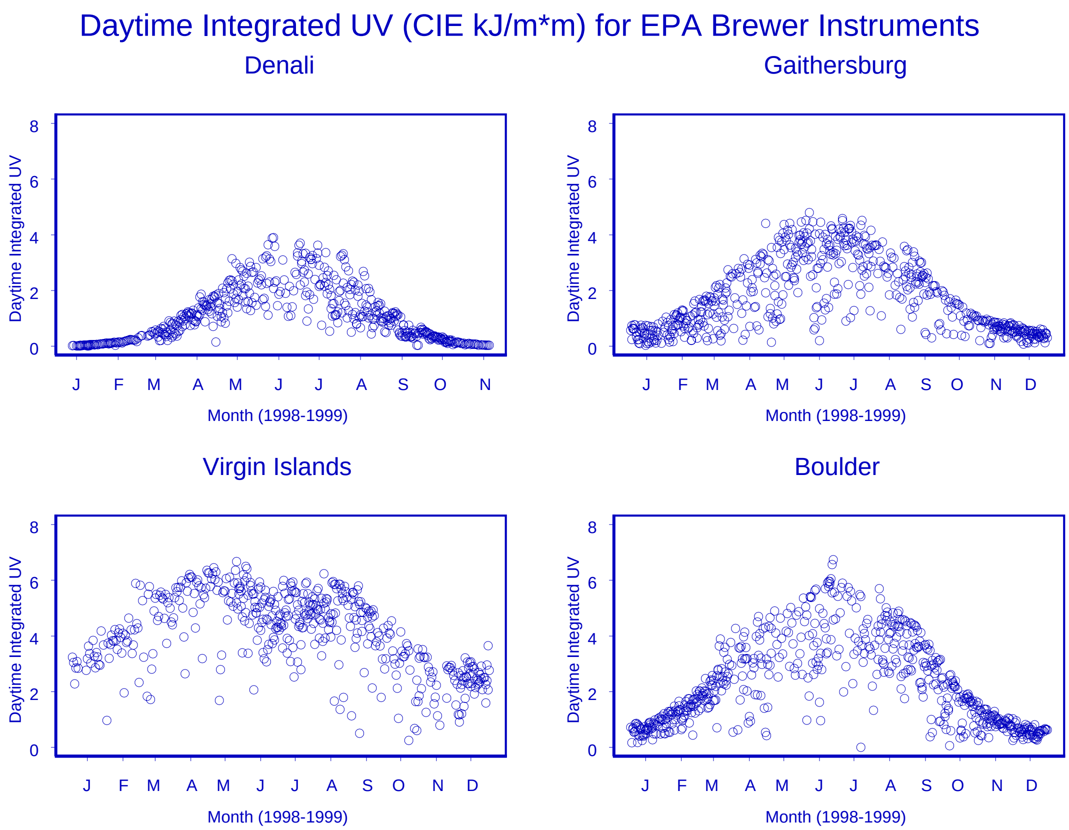

Figure 3. Daily integrated UV doses for Denali National Park (near the Arctic Circle); Gaithersburg, MD; Virgin Islands National Park; and Boulder, CO. The long days of summer sunshine increase Arctic UV doses to levels comparable to mid-latitude sites.

Ozone in the Arctic

In the past few decades ozone levels have changed throughout much of the world. While many are familiar with the depletion that has taken place over Antarctica, fewer are aware that ozone depletion has been severe over the Arctic and sub-Arctic. In fact, ozone depletion in the Arctic is second only to the depletion observed in the Antarctic. These losses are supported by both scientific measurements and observations of those who live in the Arctic. **Figures 4 and 5**, from the National Aeronautics and Space Administration, show how ozone levels between 60 and 90°N have changed over the past thirty years. We can see that there has been a considerable loss of ozone in the past decade, with large year-to-year variability. A number of scientific activities have been devoted to understanding ozone loss in the Arctic and the causes are understood to be fundamentally the same processes that deplete ozone in Antarctica and the rest of the world. However, because Arctic meteorology, especially the temperature and movements of air, is considerably different than in Antarctica, the ozone loss in the Arctic exhibits fundamentally different characteristics than the Antarctic ozone loss. To begin with, Arctic losses are less predictable from year to year than in the Antarctic. Ozone loss in the Arctic may also be strongly affected by anthropogenic climate change, which can cool temperatures in the vicinity of the ozone layer and increase ozone loss. State of the art modeling efforts indicate further ozone depletion in the coming two decades for the Arctic, however these predictions are highly uncertain at this time.

UV levels in the Arctic

UV levels have been measured in the Arctic for only the past ten to fifteen years. These measurements have been extremely useful for showing how ozone, as well as a variety of other factors, including clouds, sea ice and snow cover, can affect ultraviolet radiation. The multiple factors that influence UV imply that the relationship between ozone and UV is not, in practice, a direct relationship. In addition, measurements show that considerable amounts of UV penetrate through water, ice and snow. Quality and extent of sea ice, clouds and surface reflectivity have a large impact. Changes that may result from anthropogenic climate change, including changes to sea ice, snow cover and clouds, will have a direct influence on UV levels received in the Arctic. Thus, already highly uncertain predictions for Arctic ozone are compounded by the uncertainty in what we expect due to changes in clouds, sea ice and snow cover, making predictions for future UV levels extremely uncertain.

Changes in ozone levels in the Arctic have resulted in higher UV levels on clear sky days. Not only have measurements confirmed the changes in UV levels in the Arctic, but reports from native peoples have been documented, at least for the Inuit in the Eastern Canadian Arctic. These people report that in the last five years or so, they have been experiencing sunburns, something that had previously been very rare. Older hunters who have spent long periods of time out on the sea ice in 24-hour sunshine rarely had their skin burn in previous years. From interviews and conversations, it is evident that the sunburns are mostly a new experience, or that the burns are now more severe than the Inuit had known previously. This native knowledge provides evidence of increased UV impacts in the Arctic under a depleting ozone layer and ties our relatively recent measurements of UV into an oral historical record that spans at least several generations.

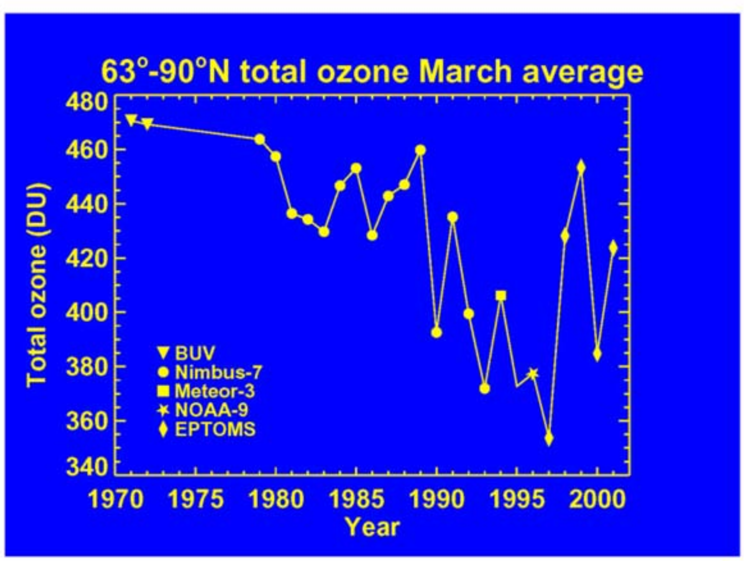

Figure 4. Time series of March total ozone averages from 63-90ºN, compiled by the National Aeronautics and Space Administration.

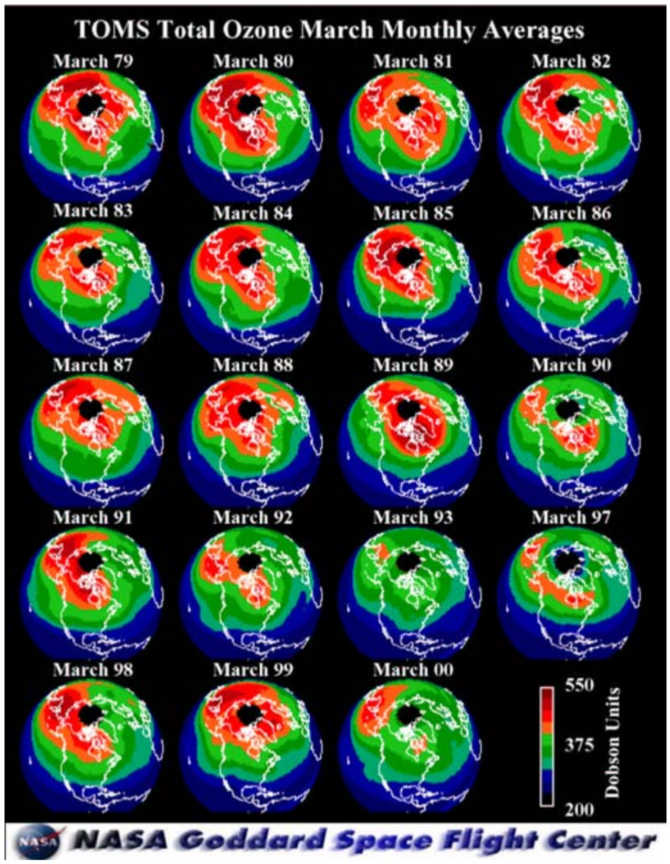

Figure 5. Distribution of total ozone over the northern hemisphere for the years 1979 to 2000. Depletion of high ozone levels over the Arctic (shown in red) has not been symmetric around the polar region.

UV Effects – overview

UV is known to affect most biological systems. Studies confirm that UV can affect human skin, eyes and immune systems. UV has a direct effect on a variety of species including the eyes of virtually all animals, fish--particularly in the egg and larval stages--and both plant growth and quality. These effects, while identified for a number of species, have not been well studied. Many species have not been examined for the impacts of UV. Ecosystem effects can be much more complicated, and less intuitive, than what we can learn from studies individual species in controlled laboratory settings. UV can also have secondary impacts, for instance by making species more sensitive to other stressors, particularly pollutants.

UV effects – humans
UV exposure has dermatological, ocular, and immune suppression effects on humans. UV radiation is related to long-term health problems such as skin cancer and other skin-related diseases, and cataracts and other eye disorders. These health issues can cost taxpayers billions of dollars each year through Medicare and other programs.

UV effects – species
Research studies have shown that phytoplankton and other organisms, including those at the base of the food web, can be particularly susceptible to UV. Changes in the populations of these species could have wide impacts upward through marine ecosystems. Many fish species, including cod, herring, pollock, and salmonids, are also UV-sensitive, resulting in the death of many of the larvae before they are able to reach maturity. These losses impact not only the diversity of the marine ecosystem, but could also be very detrimental to the fishing industry, particularly in light of the crises that have occurred in salmon fisheries in recent years.

Terrestrial plants and animals are also directly affected by ultraviolet radiation. Leaf thickness, shoot growth and chemical compositions of plants are all affected by changes in UV radiation. Long-lived animals, including dogs, can develop cataracts under the same mechanisms as humans do.

UV effects - ecosystems
UV does not affect all species equally. However, the effects of UV on one species can have immediate effects on a number of other species. The complex interactions and feedbacks within any natural system make extrapolation of laboratory studies on individual species difficult. At times the results can be counter-intuitive. For instance, while UV kills off algae in a laboratory setting, UV causes the same algae to flourish in a natural setting, because it has an even more harmful effect on the larvae that eat the algae in a natural setting. The effects of increased UV across species affects terrestrial as well as aquatic systems. There is recent evidence that increases in UV radiation increases a plant's likelihood to produce lignins and a number of ill-tasting chemicals. This in turn makes the plants less likely to be digested or even eaten by the animals that feed on them. Therefore, while the direct effects of UV may be minimal on grazing animals, the indirect effects on the quality, not quantity, of their food supply may be significant.

UV effects –combined effects
Environmental stressors, including pollutants, climate change, and water availability, can further tax a plant or animal's survival by combining nonlinearly with UV radiation. These combined effects can further threaten organisms and ecosystems, and may be much more severe than the individual impacts. For instance, recent research has explored the role of UV radiation in enhancing the toxicity of certain chemical compounds. The combination of UV light and chemical molecules, particularly those associated with oil spills or petroleum contamination, can yield an effect known as photoenhanced toxicity. This effect has been shown to seriously injure or kill species that would typically be less harmed in the presence of the chemicals alone. Pollutants and other stressors are

expected to remain significant, or as is the case for climate change, to increase in the Arctic in the coming years.

Summary

UV has long been a natural stress in the Arctic. Arctic ozone levels have decreased significantly in the last ten years with large year-to-year variability that is difficult to predict. Future ozone and UV levels are highly uncertain and difficult to predict. Both human and ecosystem health effects can be costly, not only for the individual or species, but also in terms of economic costs to Medicare and to fisheries and other industries. Medicare, for instance, pays billions of dollars every year for cataract surgery, which is the number one therapeutic procedure performed on adults over age 65. The Alaskan Arctic is currently home to approximately half a million people. Much can still be learned about the effects of UV on these people and on the plants, mammals, and fish they harvest for food. Outstanding questions still remain, and the threat of increasing UV to the peoples and ecosystems of the Arctic is far from over.

A number of international organizations, including the International Arctic Science Committee (IASC), the Arctic Monitoring and Assessment Program (AMAP) and Conservation of Arctic Flora and Fauna (CAFF) have cited the uncertainties with respect to future UV levels and their effects as being a crucial area requiring immediate investigation. The U.S. agencies are poised to address these uncertainties in a coordinate manner through the Interagency Arctic Research Policy Committee’s Study of Environmental Arctic Change (SEARCH).